Flexure on Venus

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Comparing Earth and Venus

- Drastically different atmospheres, Venus being 90 bar and having 96% CO_2 leading to high surface temperatures of ~450 C
- Otherwise, Venus is the planet most similar to Earth in terms of composition, size, and distance from sun

Surface ages

- Earth has widely varying surface ages ranging from 0, to 3.8Ga (oldest cratons) and pretty much everything in between
- Based on crater density, surface of Venus is all similar in age, ~0.5-1Ga

- Surface ages on Earth are indicative of plate tectonics as we know it, so what does this mean for Venus?
- Are there any features on Venus that may be caused by some analog to tectonic settings on Earth?

Coronae

- Magellen Altimetry data shows 20+ ‘coronae’
- Corona(singular) is the name given to these ring-like features of undetermined origin
- unique to Venus
- surrounded by ring of ridges/grooves

Possible Formation of Corona

-Forms above hot upwelling mantle plume which then thins the lithosphere.

-Massive volcanism then occurs, causing a large volcanic load.

-broken lithosphere is then allowed to bend near the edges because of the negative buoyancy.

- the bending edges are then allowed to sink into neighboring lithosphere.

Retrograde Subduction

- Coronae appear to possibly be subducting lithosphere
- Test hypothesis by checking if the overriding coronal ridge is massive enough to supply enough bending moment

$$M = \int_{-\infty}^{0} \Delta\rho g w(x) x dx$$

$$D\frac{d^4w}{dx^4} + P\frac{d^2w}{dx^2} + \Delta\rho g w = q(x)$$

No end load, P=0

$$D\frac{d^4w}{dx^4} + \Delta\rho g w = q(x)$$

Fourier Transform gives:

$$D(2\pi k)^4 W(k) + g\Delta\rho W(k) = Q(k)$$

$$q(x) = V_o \delta(x)$$

$$Q(k) = V_o$$

$$D(2\pi k)^4 W(k) + g\Delta\rho W(k) = V_o$$

$$W(k)=\frac{V_0}{D}\left((2\pi k)^4+\frac{g\Delta\rho}{D}\right)^{-1}$$

$$\propto^4=\frac{4D}{g\Delta\rho}$$

$$W(k)=\frac{V_0}{D}\left((2\pi k)^4+\frac{4}{\alpha^4}\right)^{-1}$$

$$w(x)=\frac{V_o}{D}\int_{-\infty}^{\infty}\frac{e^{i2\pi kx}}{(2\pi k)^4+\frac{4}{\propto^4}}dk$$

$k' = 2\pi k$

$dk = \frac{1}{2\pi} dk'$

$w(x) = \frac{v_o}{2\pi D} \int_{-\infty}^{\infty} \frac{e^{ik'x}}{k'^4 + \frac{4}{\propto^4}} dk'$

Roots of denominator

$(k'^2 + \frac{2i}{\propto^2})(k^2 - \frac{2i}{\propto^2})$

Taking the roots of this…

$(k' - \frac{1+i}{\propto})\ (k' - \frac{-1+i}{\propto})\ (k' - \frac{1-i}{\propto})\ (k' - \frac{-1-i}{\propto})$

Using Cauchy residue theorem for relevant poles

$$w(x)=\frac{V_o \propto^3}{8D} e^{\frac{-x}{\propto}} \left(\frac{e^{\frac{ix}{\propto}}}{1+i} + \frac{e^{\frac{-ix}{\propto}}}{1-i}\right)$$

$$w(x)= e^{\frac{-x}{\propto}} \left(c_1 \cos\left(\frac{x}{\propto}\right) + c_2 \sin\left(\frac{x}{\propto}\right)\right) + e^{\frac{-x}{\propto}} \left(c_3 \cos\left(\frac{-x}{\propto}\right) + c_4 \sin\left(\frac{-x}{\propto}\right)\right)$$

$c_3=c_4=0$

$$w(x)= e^{\frac{-x}{\propto}}(c_1\cos(\frac{x}{\propto})+c_2\sin(\frac{x}{\propto}))$$

From Johnson and Sandwell

$$w(x)= d_1 e^{\frac{x}{\propto}}\cos(\frac{x}{\propto})+d_2 e^{\frac{x}{\propto}}\sin(\frac{x}{\propto}) + d_3 x + d_4$$

Flexural Parameter in terms of elastic plate thickness (h)

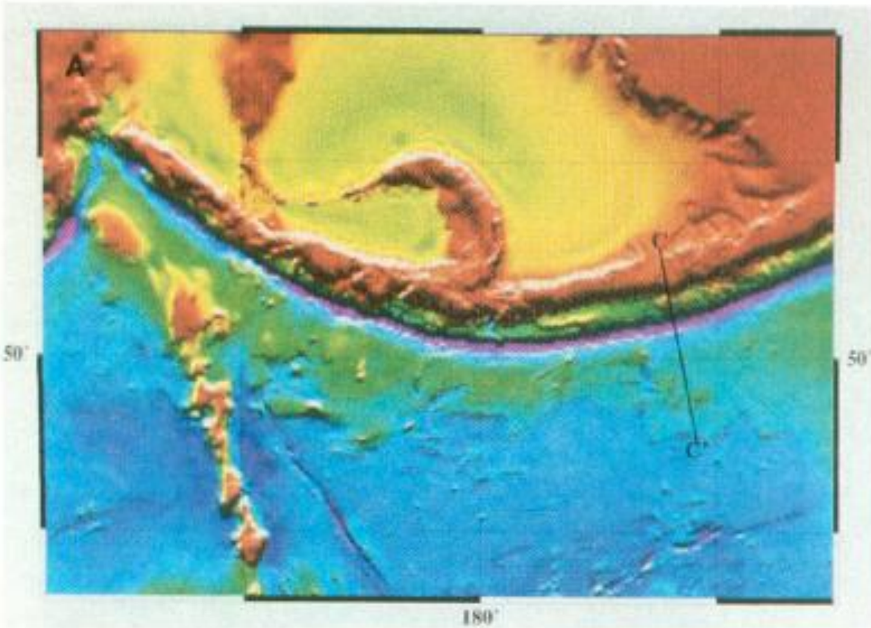
$$\propto^4 = \frac{4D}{g\Delta\rho} \quad D=\frac{Eh^3}{12(1-v^2)}$$

$$\propto^4 = \frac{4}{g\Delta\rho} \left(\frac{Eh^3}{12(1-v^2)}\right)$$

Solving for Elastic Plate Thickness

- From fitting the model to a profile across corona and getting the best fit flexural parameter, elastic plate thickness(h) can be determined

Aleutian Trench on Earth



Artemis Corona on Venus

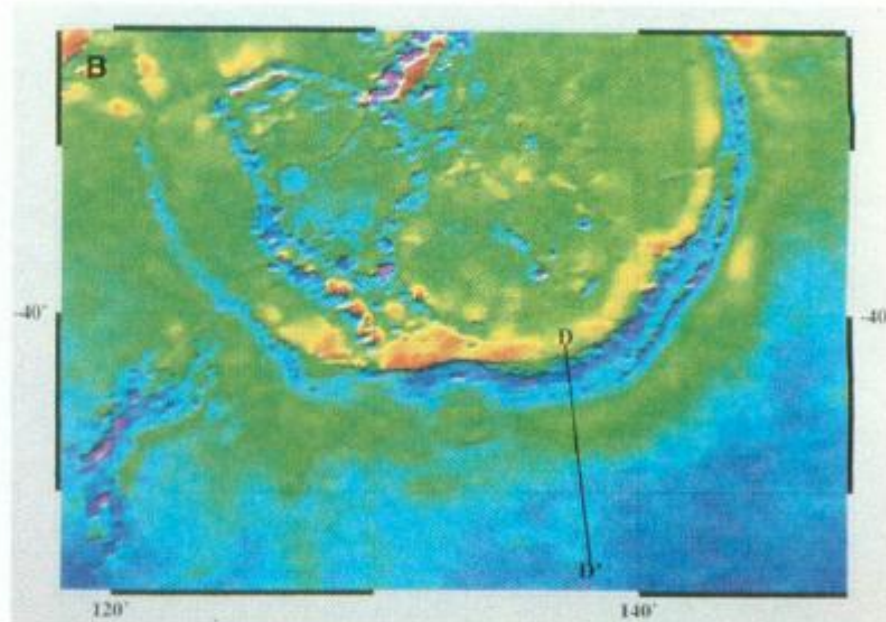
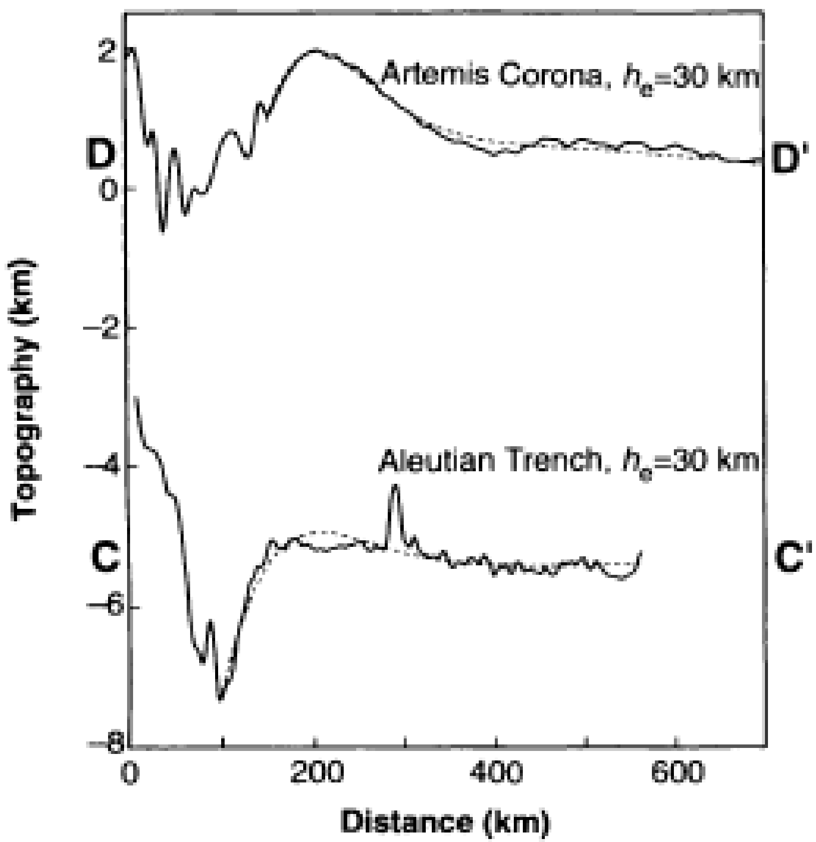
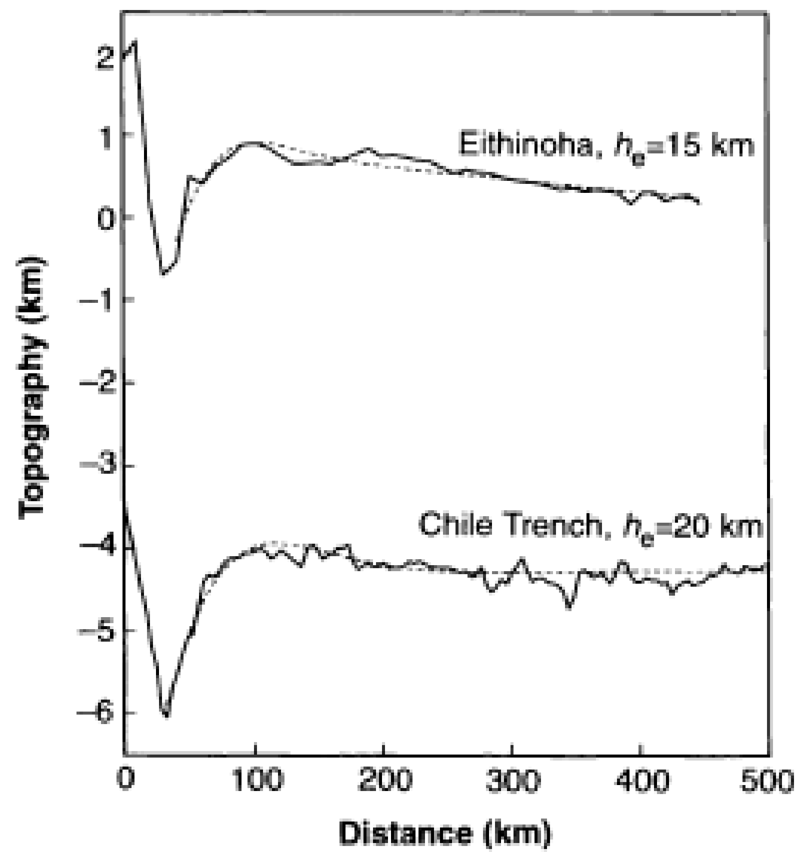


Fig. 3. (**A**) Bathymetry of Aleutian trench (North Pacific, Earth) showing a tall volcanic ridge (inside arc, orange) and a deep ocean trench (outside arc, violet). (**B**) Topography of Artemis Corona (East Aphrodite, Venus) from Magellan altimetry (*5*) displayed at the same horizontal and vertical scale as the Aleutian trench (A) to emphasize the similarities between the two trenches.

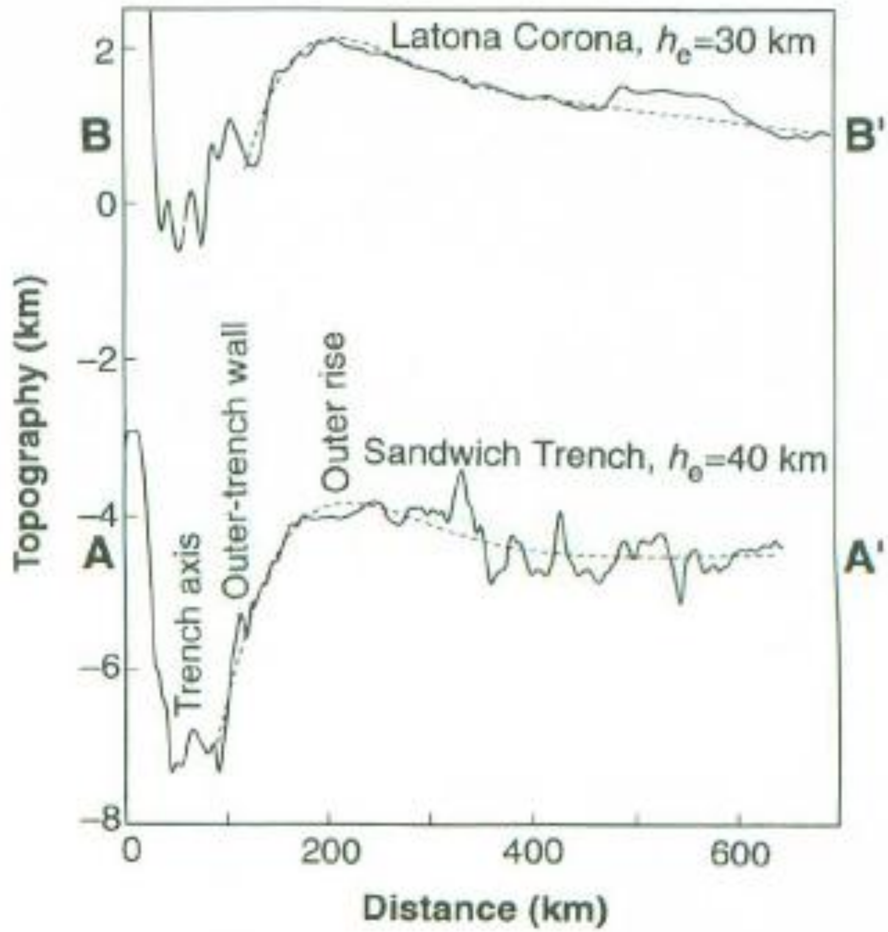
Figures at same vertical and horizontal scale

From Sandwell and Shubert





From Sandwell and Schubert


Latona Corona, h_e=30 km
Sandwich Trench, h_e=40 km
B
B'
A
A'
Trench axis
Outer-trench wall
Outer rise
Topography (km)
Distance (km)
2
0
−2
−4
−6
−8
0
200
400
600

Flexure vs Heat Flow

- Previous estimates of lithospheric thickness were 13-20km based on heat flow (assuming same mantle and surface heat flow as Earth)
- Flexure models from coronae give lithospheric thickness of 12-34km, thicknesses comparable to those of Earth's lithosphere
- To fit h estimated from flexure, mantle heat flow needs to be ~1/2 of that for Earth

Possible explanations

- Venus' mantle is drier than Earth's mantle, which influences rheology→ more viscous mantle
- A more viscous mantle would impede convection. Convection is a very efficient means of transmitting heat. Conduction is less efficient so heat flow would be smaller magnitude
- Venus may have had different methods of heat loss early in its history via extensive volcanism, causing present mantle heat flow to be lower than Earth's

Questions?

References

- Sandwell and Schubert. Evidence for Retrograde Lithosphere Subduction. 1992

- Johnson and SandwellLithospheric flexure on Venus. 1994

- Solomon. The Geophysics of Venus. 1993